awaiting investigation is whether any perceptible effect on the height and form of a mountain chain can be detected after its flanks have been convulsed with earthquakes; whether its rocks have been more tilted or folded or fractured. Men are usually too overwhelmed by the losses to life and property to take heed of such matters as these, and it may seem almost cold-blooded to suggest them for practical consideration. In all mountain districts much subject to earthquakes, it would be desirable to have an accurate system of levelling carried out, so that after a time of disturbance the heights could be checked. It would also be useful to have numerous photographs of cliffs and other sections where the rocks are well exposed, and where, therefore, any change of inclination, even to a slight extent, could be ascertained and measured. In regions where, as in the Karst, the earthquakes probably arise from the giving way of the roofs of underground tunnels or caverns, likewise in volcanic districts, the precautions here suggested might be of little use. But in those tracts where mountain-making is probably still in progress, they might supply us with many suggestive facts.

There is one other feature in the present Andalusian earthquakes to which allusion should be made. It has often been asserted and often denied that the occurrence of earthquakes is connected with the state of the atmosphere at the time. There certainly seems no doubt that in Europe, at least, the crust of the earth is considerably more convulsed by earthquakes in winter than in summer. When the shock of December 25th struck terror into the provinces of Malaga and Granada, the barometer, which a fortnight before had been remarkably steady, was exceptionally low and variable. Mr. George Higgin, of Broadway Chambers, Westminster, sends us an extract from a letter received by him from one of his engineers at Albox, in the valley of the River Almanzora, province of Almeria, not far to the eastward of the scene of disturbance. The writer, who was still unaware that there had been any earthquake, states that after December 19th a severe gale sprang up, lasting four days; the barometer varied from 29·28 on December 19th to 28·52 on the 27th, and continued to oscillate to such an extent that no trustworthy levellings could be made with it. A correspondent of the *Times*, writing on Sunday last, also mentions the low state of the barometer, and that the severest and greatest number of shocks continues to be felt from 5 p.m. till 5 a.m., and that since the outset, at intervals of about a week, the movement has shown a recrudescence with each return.

There has been also the usual chronicle of secondary effects from the earthquake shocks. Landslips have occurred, with the consequent disturbance of drainage. In one place a village has slid northwards about sixty feet, leaving a deep semicircular crevasse where it previously stood. The displaced ground has intercepted the course of an adjacent stream, so that a lake is forming behind the obstruction. At Periana a mass of rock and earth, disengaged from the slopes above, is said to have demolished a church and 750 houses. Among the numerous sulphur-springs of the region there has been considerable disturbance. Some of these sources, as has often been observed at Ve.uvius and elsewhere, disappeared after the first shock, but in a day or two afterwards began to flow again at a higher temperature than before.

THE STABILITY OF SHIPS

A Treatise on the Stability of Ships. By Sir E. J. Reed, K.C.B., F.R.S., M.P. (London: C. Griffin and Co., 1885.)

THE stability of ships is a subject that has attracted considerable attention of late. Many disasters have happened to ships through insufficient stability, and have caused scientific men as well as practical naval architects to apply themselves to a renewed and close investigation of the subject. The result is that the ideas which till late prevailed respecting it are seen to be often superficial and incomplete, and in some cases not entirely free from error.

Sir Edward Reed has done good service in bringing out a treatise upon stability which presents the matter in a fresh, readable, and instructive form. Singularly enough this is the only work in the English language which attempts to deal exhaustively with it. Notwithstanding the magnitude and complexity of the subject, and its vast importance to all who are responsible for the wise design and safe management of ships, its treatment has previously been of a very restricted and imperfect character. The student of naval science has required to consult works which range over the wide field of naval architecture, and numerous papers that lie entombed in the published proceedings of learned societies, in order to acquire anything approaching a comprehensive knowledge of the problem of stability. Sir Edward Reed has brought together and placed into relation to each other the investigations made at various times by eminent men of the science of the subject, and the practical developments which have resulted therefrom. Among these are included the researches of French mathematicians and naval constructors, which have hitherto been but little known in this country.

The statement that a floating body, such as a ship, when laden so as to float at a given draught of water may assume any position—upright, inclined, or upside down—or it may when floating upright and in equilibrium be capsized with ease or with difficulty, according to the character or degree of the stability it may possess is the veriest scientific truism. Many may suppose it to be unnecessary, in this shipbuilding country, to make so self-evident an observation. Yet trite and obvious as it may appear when put into this form, it has been strangely, almost culpably, ignored by many who are responsible for the safety of ships. Very few exact investigations of the stability of individual ships have been made till quite recently; and even those that were attempted have frequently been imperfect and inconclusive.

The correct principles upon which the stability of ships depends were not demonstrated till the middle of the last century. Bouguer explained the properties of the metacentre in 1746, and gave a formula by which its position may be calculated. He also showed how the initial stiffness, and height of centre of gravity, of a ship may be determined by a practical experiment; this being the method of inclining vessels which is at length becoming usual in this country. Bouguer's investigations were followed up and extended by D. Bernouilli and Euler; and it was shown how the righting moments at large angles of inclination from the upright may be determined.

Atwood brought forward the subject clearly and forcibly

and at considerable length, in two papers read before the Royal Society in 1796 and 1798. He laid down the fundamental formula by which the length of the arm of the righting or upsetting couple may be determined for any angle of inclination of a ship; and he showed how the several terms contained in it may be calculated. Two of these terms, viz. the volumes of the wedges of immersion and emersion, and the positions of their centres of gravity, involved very lengthy and complicated calculations. The tediousness and complexity of stability investigations have been chiefly caused by the difficulties connected with finding by actual measurement and calculation the solid contents of these wedges and the positions of their centre of gravity.

Let Fig. 1 represent the transverse section of a ship, of which W L is the line in which the plane of flotation, when the ship is upright, is cut by the plane of the paper; the centre of gravity of the whole ship being at G. Let B similarly represent the centre of gravity of the volume of the ship's displacement, or centre of buoyancy, as it is commonly called. Now, suppose the ship to be inclined a few degrees by some external force that acts horizontally, and therefore does not alter the displacement; and let

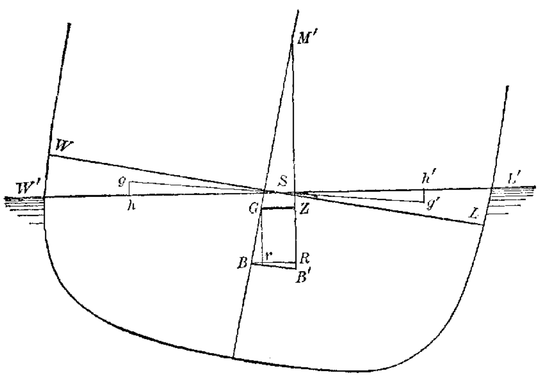

FIG. 1.

W' L' represent the new water-line. The effect of the inclination has obviously been to lift out of the water a wedge-shaped body, of which W S W' is the section, and to submerge on the opposite side of the ship another somewhat similar wedge-shaped body, of which the section is L S L'. These wedges are known as the wedges of immersion and emersion respectively. They are each bounded on the outside by the outside form of the ship, and will therefore usually differ in external form; but they must be precisely equal in volume, or otherwise the whole displacement of the ship could not remain unaltered.

The inclination of the ship through the angle W S W' has changed the position of the centre of buoyancy B to B'; and G Z is the length of the perpendicular let fall from G, the centre of gravity, upon the vertical B' M, through B'. G Z is the arm of the couple at the ends of which the weight of the ship and the upward pressure of the water act; and it is commonly called the righting arm. Atwood's fundamental formula for determining the length of the righting arm is—

$$GZ = v \times hh'/V - BG \sin \theta,$$

v being the volume of either of the wedges W S W', L' S L; hh' the distance, measured parallel to W' L', between g and g', the centres of gravity of these wedges; V the volume of the ship's displacement; and θ the angle of inclination W S W'.

It is obvious that the labour of calculating the volumes and positions of centres of gravity of such irregularly shaped bodies as the wedges of immersion and emersion must be very great. The labour and difficulty are further increased by the necessity of drawing the inclined water lines, such as W' L', in positions which give equal volumes for these wedges. The point S, where the inclined water-line intersects the upright water-line, thus requires to be determined separately for each angle of inclination. Atwood's manner of approximating to the volumes and moments of these wedges was simplified by Mr. S. Read. The method which has commonly been adopted in recent years is, however, one brought forward at the Institution of Naval Architects, by Mr. F. K. Barnes, in 1861.

The old systems of stability calculation, even as modified by Mr. Barnes, were so excessively laborious and complex, that very few attempts were ever made to apply them to ships. The initial stiffness, as determined by the metacentric height, was practically the only element of stability that was investigated. It appears that, prior to 1867, no calculations were made which showed how the stability of a ship became affected by inclining her till the water-line came up over the deck, or at what angle the stability vanished. This was done for the first time at the Admiralty in 1867 by Mr. William John, under the direction of the author of the present work. The results of these investigations were published by Sir E. J. Reed in an interesting and instructive paper upon "The Stability of Monitors under Canvas," read before the Institution of Naval Architects in 1868. Curves are appended to this paper which show how the righting moments vary at successive angles of inclination, and the point at which they vanish. This paper proved conclusively how great are the dangers that have to be guarded against in ships of low freeboard and with high centres of gravity.

The extended application of stability calculations to cases involving greater irregularities in the volumes of the wedges of immersion and emersion than are contemplated by Atwood—such, for instance, as are caused by deck edges becoming immersed, or portions of deck erections becoming included in the volumes of the immersed wedges—created a demand for still more systematic and simple modes of calculation. This was supplied by Messrs. White and John in a paper read before the Institution of Naval Architects in 1871.

Down to the time of the *Daphne* disaster, which occurred in July, 1883, stability calculations made no further progress of importance in this country. At the Admiralty, and in some of our mercantile shipyards, the processes above described were gone through in cases where full knowledge of a ship's stability was considered requisite. Such calculations often took about a month to complete; and the results obtained were usually limited to a knowledge of how a ship's righting moment varied with angle of inclination at one or more chosen draughts of water. Even this was not considered essential when very light draughts of water were being dealt with.

The evidence given at the *Daphne* inquiry, and the

report of the Government Commissioner, Sir E. J. Reed, directed attention to imperfections in this department of shipbuilding practice, and furnished a powerful stimulus to renewed inquiry. Valuable results were speedily forthcoming in the shape of more complete and general expositions of the theory of stability than had previously been given: and in a great simplification, which at the same time included an extension, of the system of calculation. One of the most useful portions of the present work is that which describes the improvements thus made in the theory and practice of the subject.

The modern improvement of the theory is shown by Sir E. J. Reed to be in the direction of considering the variation of stability with draught of water, and the amount of stability a ship will possess at light draughts. The *Daphne* inquiry showed that the danger of instability which is sometimes to be found associated with light draught of water was frequently lost sight of because of a prevailing belief that, so long as a vessel has a high side out of water, and any initial stiffness, she will have a large range of stability. This point is clearly and fully dealt with by Sir E. J. Reed in his present work; and he states a general proposition which underlies it, and which was first enunciated by Prof. Elgar in the *Times* of September 1, 1883. It is that, if any homogeneous body which is symmetrical about the three principal axes at its centre of gravity be of such density as to float in equilibrium with its lowest point at a depth x below the water, then if the density be altered so as to make it float with its highest point at a height x above the water, the righting moments will be the same in both cases at equal angles of inclination, and, consequently, the range of stability and complete curves of righting moments will be the same. Sir E. J. Reed also gives copious extracts and diagrams from a paper read by Prof. Elgar before the Royal Society in March last, in which the variation of righting moment with draught of water is shown not only for symmetrical bodies, but also for floating bodies of irregular form and for an actual ship. These investigations indicate that the effect of lightness of draught upon stability may be as prejudicial, or even more so, than that due to low freeboard.

Sir Edward Reed deals very fully with the recent practical developments of the subject, and with the improved systems of calculation that have been devised. These have for their primary object the direct construction of curves showing the variation of righting arm with draught of water at fixed angles of inclination. The wedges of immersion and emersion are no longer dealt with in the stability calculations. Atwood's formula involving the volumes and moments of the wedges of immersion and emersion is discarded, and the following one is employed (see Fig. 1) $GZ = BR - BG \sin \theta$. BR is computed by calculating the under-water volume at the inclined water-line $W'L'$, and its statical moment. These calculations can be made very quickly and easily with the aid of Amsler's mechanical integrator: and the complication involved by dealing with the two separate wedges, and equating their volumes, may thus be avoided. Sir Edward Reed describes the methods put forward by Mr. W. Denny—who appears to have been the first to suggest this important step—Mr. Macfarlane Gray, Mr. Benjamin, and others.

It is singular that while naval architects in this country were thus working out for themselves those extensions of the difficult problem of stability which modern requirements have demanded with continuously increasing force, the French appear to have been long in possession of a complete and admirable system. So long ago as 1863 M. G. Dargnies was making calculations of stability at Marseilles for numerous angles of inclination, and for four or five draughts of water; and in 1864 M. Reech put forward a most ingenious and perfect method for bringing all the probable stability conditions of a ship into full view and under calculation. The advantages of this method were so striking that it was not long in becoming practically adopted in France, and, in 1870, M. Risbec prepared a paper upon it, together with a calculation form for facilitating its application. Sir Edward Reed gives a concise and clear exposition of the systems of MM. Dargnies, Reech, and Risbec, together with an example of M. Risbec's calculation form. The investigations of MM. Ferranty and Daymard are also described in detail. The latter are probably better known in this country than any of the others referred to, in consequence of a paper which M. Daymard read upon the subject before the Institution of Naval Architects in April last.

There is much in this large and important work to which it is hardly possible to refer, still less attempt an adequate discussion of, within the limits of a short review. We shall return to the subject in a future number. In the meantime, all who are interested in this branch of science, and its bearing upon the construction and safe treatment of ships, will do well to refer to the book itself for full and precise information upon the various aspects of the theory of stability and its practical applications. Fundamental principles are clearly described and illustrated, and may be readily understood by persons possessing an elementary knowledge of mathematics. On the other hand, the elegant and extensive investigations of Dupin, Leclert, Guyou, Moseley, Woolley, and others furnish profitable subjects of study for the most advanced of mathematicians.

(*To be continued.*)

OUR BOOK SHELF

Natural History Sketches among the Carnivora, Wild and Domesticated; with Observations on their Habits and Mental Faculties. By Arthur Nicols, F.G.S., &c. (London: L. Upcott Gill, 1885.)

THIS little volume of some 250 pages is full of interest: treating somewhat of lions and tigers, it has a pleasant portion of a chapter about cats, but the bulk of the volume is devoted to man's faithful friend, the dog. Of the several excellent illustrations we would especially mention the life-like one of a lioness watching its prey, from a drawing by Mr. J. T. Nettleship, which is very full of vigour and muscular force, one of the black-maned African lion, by Mr. C. E. Brittain, and one of Chang, Mr. G. B. Du Maurier's Grand St. Bernard, by Mr. T. W. Wood. As one of the interesting subjects touched on by Mr. Nicols, we may allude to that treating of the sense of smell in dogs. He alludes to this in connection with the habit possessed by some dogs of rolling in decaying animal, or even vegetable, substances. On one occasion Mr. Nicols noticed his retriever vigorously anointing himself by rolling about in a clump of living fungi which emitted a particularly evil smell. This is thought to be an inherited habit, or, as Mr. H. Dalziel writes, "Taste and smell being